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ABSTRACT

Harvard's energy conservation plan is presented in detail with the hope that it will suggest practical, cost-effective energy-saving ideas to other institutions, and to dispel frequently-expressed fears concerning the feasibility and acceptance problems of this type of program. The total energy plan incorporates numerous specific elements that should be seen not in isolation but as components of the overall system. It enabled Harvard to save an estimated $2.5 million in energy costs in fiscal 1975. This dollar amount reflects even more impressive savings in real terms, since the dollar cost of energy has continually increased, offsetting the university's savings in efficiency. The use of the graph factor is described, along with the emphasis on results, the critical human element, automation and computerized systems, the university's Planned Energy Preservation (PEP) team, the Harvard Inspection Team (HIT) truck for preventive maintenance, the use of storm windows, and planned construction of a revolutionary total energy plant. The future outlook for energy conservation is assessed. (LBH)

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Energy Planning: A Total Concept

by Stephen S. J. Hall

In recent years, as conservation has become a topic of concern to public and private energy users alike, there has been increased interest in developing innovative solutions to the energy problem. This was especially dramatized by the energy crisis in 1973, but is of ongoing concern, particularly to those involved with energy control on a large scale.

Harvard University has pioneered among educational institutions in the development of a total energy plan — combining awareness campaigns, preventive maintenance, and physical plant improvements with an innovative, computerized control system. Overall, the goal of the total energy plan is to make the basic system for the use of energy more efficient; to realize savings without experiencing curtailment of service.

Most of the conservation activities undertaken at Harvard, while somewhat avant-garde, are not beyond the reach of anyone responsible for the efficient use of energy in the operation of buildings, either in private industry or in institutions such as colleges, universities, and hospitals. Harvard's plan is neither overly elaborate nor so specialized as to preclude its adaptation for other institutions. In fact, it is based almost entirely on common sense and realistic acceptance of the fundamental issues of awareness, efficiency, action, and results.

The dual purpose of this article is to present Harvard's energy conservation plan in detail, with the hope that it will suggest practical, cost-effective energy-saving ideas to other institutions, and to dispel frequently-expressed fears concerning the feasibility and acceptance problems of this type of program.

The total energy plan incorporates numerous specific elements which should be seen not in isolation but as components of the overall system. It is the unique combination of many factors, with the resultant synergy, which enabled Harvard to save an estimated $2.5 million in energy costs in fiscal 1975. This dollar amount reflects even more impressive savings in real terms, since the dollar cost of energy has continually increased, offsetting Harvard's savings in efficiency. The exhibit shows the relationship of real consumption in units and the dollar cost of energy at Harvard since 1971.

Use of the Graph Factor

Because dollar savings account for only part of the actual energy use reduction, an efficiency measure — the graph factor system — has been developed to determine *real* energy savings. The graph factor technique compares actual energy consumption (measured as utilities consumption) with a theoretical factor based on optimum conditions. The principle is based on the theory that proper consumption of steam, fuel, water, and electricity depends basically on the nature and amount of activity in a given building (classroom, dormitory, office or other) combined with such factors as size of the structure and weather conditions. Thus, comparison of utility consumption between one period and another cannot be made without considering the nature of the operations and conditions that affected the building during these periods. Nor can two different buildings be meaningfully compared.

To illustrate the graph factor method, the assumption which has been applied to steam is that .7 pounds of steam per heating degree day are required to heat 1,000 cubic feet of space. A building which used steam at exactly this rate would have a graph factor of 1.00. Harvard staff have developed a graph factor for each building currently being monitored, based on the specific conditions within that building. The availability of comprehensive historical data facilitates accurate comparison of efficiency in present consumption with prior years. For instance, the aggregate graph factor for the university in fiscal 1975 was 1.48

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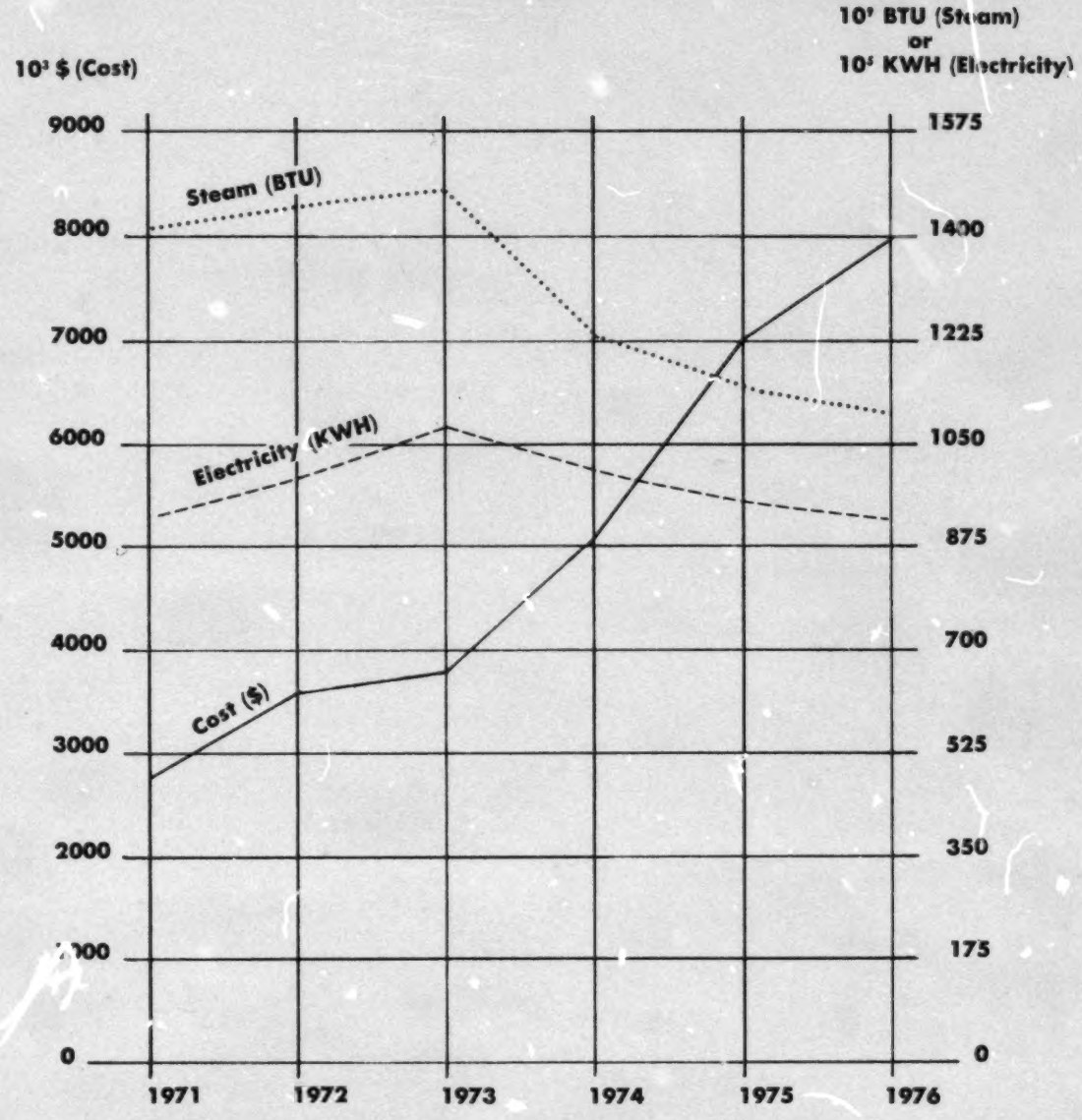
Figure 1

Graph of Annual Consumption and Cost
For Steam and Electricity on Distribution Systems
Fiscal Years 1971 Through 1976



compared with 1.73 the previous year. This reflects an improvement of 14.45 percent.

The most crucial impact of the graph factor system is its ability to provide immediate awareness of problems so that they can be corrected as rapidly as possible. Therefore, systemwide graph factor data are updated daily. If a problem were allowed to persist until discovered by a user or until the occurrence of some longer-term indicator such as the monthly financial statement, substantial waste would inadvertently result.

Emphasis on Results

A typical problem involved in the study of energy conservation is the tendency to ascribe undue importance to the quantification of relationships among critical variables in the system. Harvard staff have deliberately avoided excessive mathematical detail of this type, however, recognizing that there are virtually infinite potential energy-saving ideas which could constitute variables, and that their creative application should not be restricted by conventional formulas. In some instances, a specific improvement — either physical, such as storm windows, or behavioral, such as an awareness campaign — is credited as the most obvious energy saver. However, a broad perspective on the aggregate effect of many factors, with an emphasis on *results*, permits valuable planning and experimental flexibility, which allows new ideas to be constantly incorporated into the total energy plan. The need for this flexibility is a crucial element in the development of any energy conservation effort.

Awareness and the Critical Human Element

At Harvard, energy control systems are monitored both by people and by computer, and in several different ways, but it is recognized that the total system can be only as good as the people who maintain it. While machines can provide data, it is people who determine what data are relevant and how to use them. The system is structured for maximum awareness both among persons directly responsible for energy conservation and those who are routine users.

There have been frequent awareness efforts during the last several years, including mailers, energy bulletins, posters, lapel buttons, and the use of a conspicuous energy conservation logo on maintenance vehicles involved with conservation. A special telephone line was installed in 1973 to solicit conservation suggestions from all members of the university community. This has been widely publicized, resulting in many ideas, which have been implemented when feasible.

As with many forms of change in a large and complex institution having interacting areas of responsibility and budgetary constraints, it appeared difficult at first to obtain the necessary level of commitment to the total energy plan — particularly when major investments were required by individual facilities. Gradually, however, the plan has proven itself and gained wide acceptance.

Use of Automation and Computerized Systems

A Honeywell Delta 2500 system centrally located in Harvard's new chilled water plant currently monitors energy use in approximately 160 of the university's 357 buildings. The total cost of the system on completion will be approximately $4 million. Additional buildings are being connected to the system regularly, either by coaxial cable in nearby areas or by telephone in more remote locations. A sophisticated weather station, also located in the chilled water plant, enables operators to maintain constant awareness of weather conditions which affect energy use.

The Delta 2500 has the ability to automatically turn on and off heating and air-conditioning equipment and heavy machinery. It is programed with daily schedules for turn-on and turn-off in the various areas of the buildings it serves. For example, it may turn on the heat in a given auditorium each day at 9 a.m. and off at 4 p.m.; or the heat may be turned on only on Tuesday from 9 to 11 a.m. for a specific single class. Schedule changes are updated each day. Energy use in all the buildings eventually will be monitored by the Delta 2500. The system also includes university-wide fire alarm protection.

Supplementary memory and capacity to execute more sophisticated programs are contained in a Honeywell 316 computer, a separate component of the Delta system. This will enable new and more complex energy monitoring systems to be added gradually.

An important use of the computerized system, now in the process of implementation, is the ability to establish priorities for use of heat and electricity. Because of the demand factor billing system used by steam and electricity suppliers, lowering peak energy use is a particularly critical means of reducing energy cost. The demand factor is the charge for the utility company's maintaining peak demand capacity over a twelve-month period. This means that the peak fifteen-minute demand for steam in a twelve-month period is the amount billed as steam demand for that period. Likewise, the demand charge for electricity is based on 95 percent of the peak demand.

Obviously, there is very significant seasonality in the demand for energy, particularly for steam. The amount of steam used at Harvard in fiscal year 1975 varied from approximately 36,000 units to approximately 120,000 units per month from summer to winter (a unit is defined as 1 million BTUs).

Identified means of damping peaks in energy demand include turning off heavy machinery during hours of peak electricity consumption and allowing the temperature to drop slightly below the usual lower limit of 65° F. on very cold days or to rise slightly above the upper target of

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80° F. on very hot days. In this range the cost of air conditioning increases approximately 6 percent for each degree the temperature is lowered.

The Delta system is scheduled to be programed eventually to incorporate energy priorities so that the computer will automatically turn off specified equipment when peak demand is approached. Even without the use of the automated system for peak demand control purposes, Harvard has realized savings of approximately $30,000 per year since 1972 in steam demand. Savings also have been effected in electricity demand charges, although the potential for electricity savings has not yet been fully exploited.

PEP Team Controls Demand Peaks

The people responsible for controlling demand peaks are Harvard's Planned Energy Preservation (PEP) team. The PEP team consists of sixteen employees of the utilities division equipped with highly maneuverable and conspicuous (for awareness purposes) three-wheeled vehicles, and its members make regular visits to buildings throughout the university to turn nonautomatic heating and electrical equipment on and off at the most advantageous times. For example, a PEP team representative may arrive regularly at a building at 6 a.m. to turn on the heat, insuring that the temperature will be at least 65° F. by the time occupants arrive for work at 9 a.m. Perhaps the PEP worker will return at 4 p.m. to turn the heat off if it has been determined that the building will not cool below 65° before the last employee leaves for the day. Thorough studies have been undertaken throughout the university to determine areas of real energy inefficiencies and eliminate them, rather than to burden users with deprivation. As a result, there nas been very little visible change in service, despite the great savings in energy use.

In addition to the PEP teams which control energy use university-wide, each building has its own energy monitor (an employee, resident, or other energy user) whose responsibility is to observe additional ways in which energy savings could be accomplished; to increase occupant awareness of conservation efforts; to field energy-related complaints from employees, thus assuring them that the conservation program does not intend deprivation; and to inform the department of buildings and grounds of maintenance needs which could result in improved energy efficiency if corrected.

HIT Truck Offers Preventive Maintenance

Another important component of Harvard's total energy plan is the Harvard Inspection Team (HIT) truck. This is a fully equipped preventive maintenance vehicle whose operators (a plumber, an electrician, and a property maintenance worker) are trained to identify areas in which energy savings could be realized through repairs or replacement to the physical facilities. HIT personnel examine each building thoroughly on a scheduled basis, make small repairs themselves, and recommend larger improvements as needed.

This emphasis on recognizing the need for capital improvements combines with other features of the total energy plan to eliminate waste by causing the basic physical plant to function as efficiently as possible. Physical improvements such as the addition of storm windows and insulation and the control of exhaust fans and chimney dampers have often obtained spectacular results, particularly in the older buildings. In addition to conserving energy, capital improvements have often yielded such dramatic returns in cost savings that the results have persuaded various faculties to approve capital improvements which they might otherwise have opposed.

The Use of Storm Windows

One such capital improvement which has produced impressive results is the use of storm windows. To date, few educational institutions have installed storm windows on a consistent basis, citing various reasons for reluctance to make this investment. Primary among them are a general lack of information about storm windows and scarcity of data proving their effectiveness.

Recently Harvard undertook an exhaustive study — including both in-house and independent analyses — comparing available storm sashes and their relative merits. The study found that a high-quality, effective storm window was available, or could be designed, for every potential application.

Because of Harvard's unique historical significance, esthetics and security were particularly important considerations. In some instances, for example, custom-made windows were required to complement the appearance of buildings like Massachusetts Hall, built in 1720; similarly, special glass was selected in some cases for security purposes.

The most important precept to develop from Harvard's analysis of the storm sash issue is the necessity of evaluating a window over its total lifetime, rather than buying on the basis of initial cost. Good service and good results, with no "hidden extras," are crucial elements in an accurate comparison of value.

Harvard has already installed storm windows in forty-nine buildings and intends installation in thirty-one more in the near future. While the results obtained have varied from one building to another, and have ranged from modest to spectacular, there has been no case in which the investment has not yielded a valuable return — both in dollars and in real energy savings. The most impressive example of results to date has been a dormitory which has experienced a 1.4 years' payback on the windows.

The Total Energy Plant

After extensive analysis of the energy needs of the University Medical Area, Harvard administrators expect to begin construction this fall of a revolutionary multi-million dollar total energy plant, which promises to cut sharply the energy costs of eight local hospitals. The total energy approach is based on the principle that substantial economies can be effected by using the by-products from one process as the prime materials for another. For example, when electricity is produced steam is a by-product which can be used as a heat source. The plant will also produce chilled water for economical air conditioning. To give some indication of size, the plant can produce 900,000 lbs. of steam per hour from five steam boilers, plus 94,000 lbs. per hour from heat recovery boilers, and it can dispose of some 40 tons of trash and refuse per day. In addition, the plant has the capacity to produce 50,000 kilowatts of electricity and 20,000 tons of refrigeration.

The integrated nature of utility production in the total energy plant permits a more efficiently designed system than is possible when individual utilities are produced independently at separate locations. A further advantage of the total energy plant is that it has been designed with unusual flexibility in fuel requirements, so that subject to certain limitations, the most economical fuel at a given time can be used.

The Future Outlook for Energy Conservation

Revolutionary energy sources and conservation measures such as solar energy or large-scale energy storage may now seem remote and futuristic. While solar energy has been the subject of extensive experimentation, it has yet to become economically feasible.

There is the intention to install solar panels on at least one building at Harvard on an experimental basis within the next year. A solar energy committee is currently studying the various available panels, recent technological developments, and the most viable applications.

Another area for future exploration which interests conservationists is the principle of an energy storage bank — broadly analogous to a battery — which would enable low-cost energy to be stockpiled to fill peak needs.

While these and other ideas are being developed, however, it is important to focus on means of allocating energy resources wisely and efficiently within the limits of present knowledge.

Conclusion

It is sometimes tempting to despair of finding the optimum solution to a complex problem, or of acquiring the necessary financial support, or of obtaining the necessary commitment to an unpopular or threatening project. Those who have achieved little or no practical success with conservation programs, or who have been reluctant to undertake such programs, often cite as their most formidable obstacle the opposition or lack of cooperation of critical factions in whatever organization they represent.

In a sense, Harvard was fortunate that its energy conservation efforts gained impetus from the topical public concern about energy during the wide-spread shortages in 1973; nevertheless, the university encountered much of the usual resistance. It is in this context that Harvard may be the most useful prototype for other institutions — as an organization which met substantial resistance to energy planning initially and which gradually overcame the opposition with tangible results.

Of course, there were skeptics at first, as there are in any organization when change is introduced. There were some who feared inconvenience and deprivation, and others who were reluctant to commit scarce financial resources to an investment in energy control automation, or even storm windows, before these projects had a proven performance record. It was not until the commitments of some departments realized dramatic returns that others were persuaded to participate. Now, even the most risk-averse elements have been convinced, through irrefutable results, that there is real merit — measurable in financial as well as conservationist terms — in the total energy plan.

No experienced administrator would contend that such change does not take time to gain acceptance or that it does not, perhaps, threaten morale temporarily; however, it is as spurious to consider opposition an insurmountable obstacle to a conservation program as it is to deny the possibility of any other form of progress.